Water Quality Index (WQI) under Climate Change Impact

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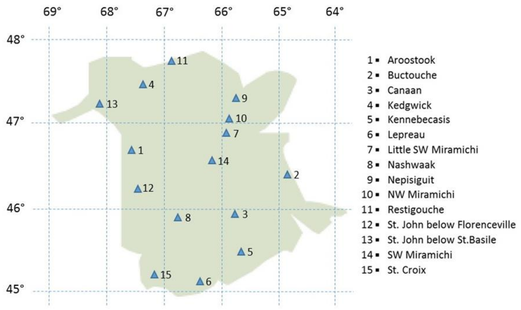
Abstract

In this study, surface water quality indices and water quality parameters under various climate change scenarios in relationship with stream temperature were modeled. Future climate data were extracted from the Canadian Coupled General Climate Model (CGCM 3.1/T63) under the greenhouse emission scenarios B1 and A2. The surface water quality of 15 rivers of New Brunswick on the basis of 9 parameters using climate change scenarios B1 and A2 were analyzed. A Weighed method and the Canadian Council of Ministers of the Environment (CCME) method were used to assess the water quality for each river under present and future climate. The knowledge gained from this study will enable engineers and water resources managers to better understand the rivers thermal regime and climate change impact on water quality related to Drinking Surface Water.

Study area

The study area consists of 15 rivers in New Brunswick. New Brunswick lies on Canada's Atlantic coast, and is bordered by the ocean on its southern (Bay of Fundy), northern and eastern (Gulf of St. Lawrence) shores. Generally, average air temperatures in New Brunswick range from -10°C in January to 19 °C in July. New Brunswick receives approximately 1100 mm of precipitation annually, with 20 to 33% falling in the form of snow. Precipitation tends to be highest in southern parts of the province and the northern part of New Brunswick receives correspondingly higher amounts of precipitation in the form of snow due to colder winters.



Water Quality Index (WQI)

1-CCME WQI Method

$$CCME\ WQI = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}$$

$$F_1(Scope) = \left(\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right) \times 100$$

$$F_2(Frequency) = \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right) \times 100$$

$$F_3(Amplitude) = \frac{nse}{0.01\ nse + 0.01}$$

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\#\ of\ tests}$$

$$excursion_i = \frac{FailedTestValue_i}{Objective_j} - 1 \quad (TestValue < Objective)$$

$$excursion_i = \frac{Objective_j}{FailedTestValue_i} - 1 \quad (TestValue > Objective)$$

CCME WQI parameters and objectives

- dissolved oxygen (DO), 5.5 mg/l
- conductivity (Cond), 500 µS/cm
- pH, 6.5-9
- total phosphorus (TP), 0.05 mg/l
- water temperature (Tw), 15 °C
- ammonia (NH3), 0.05 mg/l
- nitrite (NO2), 3.2 mg/l
- nitrate (NO3), 45 mg/l
- suspended solids (SS), 20 mg/l

WQI Ranking

95 - 100	Excellent
80 - 94	Good
65 - 79	Fair
45 - 64	Marginal
0 - 44	Poor

2-Weighted WQI Method

$$WQI = \frac{\sum_i C_i P_i}{\sum_i P_i}$$

C_i : Normalized value of the water quality parameters;

P_i : Relative weight (1 to 4):

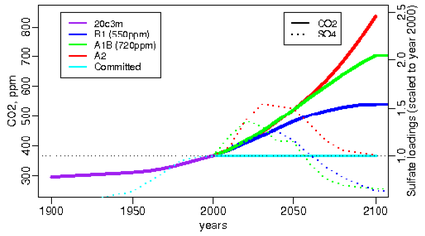
- $P_i = 4$ most importance
- $P_i = 1$ minor importance

Weighted WQI parameters and objectives

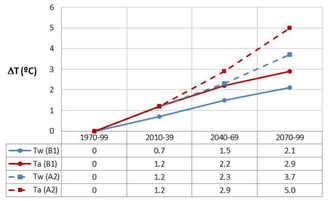
	P_i	C_i						
		100	90	80	70	60	50	40
DO (mg/l)	4	7.5	7	6.5	6	5	4	3.5
pH	1	8.0	7.5	7.0	6.5	6.0	5.5	5.0
TP (mg/l)	1	0.05	0.2	0.5	1	1.5	2	5
Cond (µS/cm)	2	200	300	400	500	600	700	1000
Tw (°C)	4	15	18	20	22	24	26	28
NH3 (mg/L)	3	0.01	0.05	0.1	0.2	0.3	0.4	0.5
NO2 (mg/L)	2	0.005	0.01	0.03	0.05	0.1	0.15	0.2
NO3 (mg/L)	2	0.5	2	4	6	8	10	15
SS (mg/L)	4	20	40	60	80	100	120	160

Climate change modelling

Climate data were extracted from the Canadian Coupled Global Climate Model (CGCM3.1 / T63) under the green house gas emission scenarios 20C3M, B1 and A2 defined by the Intergovernmental Panel on Climate Change (IPCC).



Water temperature in New Brunswick, for all future time slices (2020's, 2050's or 2080's) and scenarios (B1 or A2), were estimated as:



$$T_w \sim 0.7\ T_a$$

T_w : water temperature (LSWM)
T_a : air temperature (Doaktown)

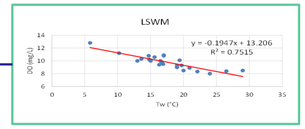
Air temperature increases ΔTa constant throughout the province (from earlier study, 2010)

	Scenario B1			Scenario A2		
	2010-39	2040-69	2070-99	2010-39	2040-69	2070-99
Aroostook	1.2	2.2	2.9	1.5	3.3	5.3
Charlo	1.2	2.2	2.9	1.4	3.2	5.2
Chatham	1.2	2.2	2.9	1.4	3.2	5.2
Doaktown	1.2	2.2	2.9	1.2	2.9	5.0
Fredericton	1.2	2.2	2.9	1.5	3.2	5.3
Moncton	1.2	2.2	2.9	1.5	3.2	5.3
Saint John	1.2	2.3	3.0	1.5	3.2	5.3

pH, TP, Cond, NH3
NO2, NO3, SS
(unchanged in time)

+

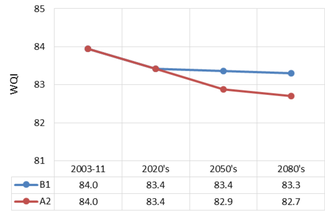
Tw = 0.7 Ta
DO =-0.1947 Tw + 13.206



WQI (future value at LSWM)= f(pH, TP, Cond, NH3, NO2, NO3, SS, Tw+0.7·ΔTa, -0.1947(Tw+ 0.7·ΔTa)+13.206)

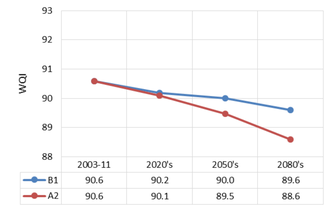
Results

a) CCME - WQI



	2003-11	2020's	2050's	2080's
B1	84.0	83.4	83.4	83.3
A2	84.0	83.4	82.9	82.7

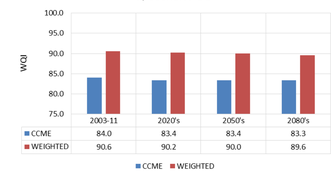
b) Weighted - WQI



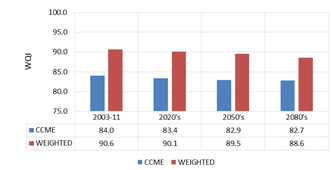
	2003-11	2020's	2050's	2080's
B1	90.6	90.2	90.0	89.6
A2	90.6	90.1	89.5	88.6

Averaged WQI decreases in New-Brunswick under B1 & A2 scenarios a) CCME method b) Weighted method

a) Scenario B1



b) Scenario A2



Comparison of CCME WQI and WEIGHTED WQI using a) scenario B1 b) scenario A2

Conclusions

- WQI values for NB rivers were calculated using two methods : CCME & Weighted
- NB rivers showed "good" water quality
- Future WQI values were estimated using Ta-Tw and DO-Tw relationships
- Climate change under scenarios B1 and A2 showed little impact on WQI

References

- El-jabi, N., Caissie, D., Hébert, C., and Turkkan, N. 2014. Water quality index under climate change impact. Report prepared for the New Brunswick Environmental Trust Fund (ETF)
- Caissie, D., El-Jabi, N. and Turkkan, N. 2014. Stream water temperature modeling under climate change scenarios B1 & A2. Can. Tech. Rep. Fish. Aquat. Sci. (in press)
- Climatic and Hydroscience Lab (**www.umoncton.ca/hydro**)